# APPENDIX C

# PROTOCOL
# FOR THE ASSESSMENT OF
# STREAM BOTTOM DEPOSITS

**New Mexico Environment Department**
**Surface Water Quality Bureau**

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## Introduction

Clean stream bottom substrates are essential for optimum habitat for many fish and aquatic insect communities. The most obvious forms of degradation occur when critical habitat components such as spawning gravels (Chapman and McLeod, 1987) and cobble surfaces are physically covered by fines thereby decreasing intergravel oxygen and reducing or eliminating the quality and quantity of habitat for fish, macroinvertebrates and algae (Lisle, 1989; Waters, 1995). Chapman and Mcleod (1987) found that size of bed material is inversely related to habitat suitability for fish and macroinvertebrates and that excess sediment decreased both density and diversity of aquatic insects. Specific aspects of sediment-invertebrate relationships may be described as follows: 1) invertebrate abundance is correlated with substrate particle size; 2) fine sediment reduces the abundance of original populations by reducing interstitial habitat normally available in large-particle substrate (gravel, cobbles); and 3) species type, species richness, and diversity all change as particle size of substrate changes from large (gravel, cobbles) to small (sand, silt, clay) (Waters, 1995).

In addition, sediment loads that exceed a stream's sediment transport capacity often trigger changes in stream morphology (Leopold and Wolman, 1964). Streams that become overwhelmed with sediment often go through a period of accelerated channel widening and streambank erosion before returning to a stable form (Rosgen, 1996). These morphological changes tend to accelerate erosion, thereby reducing habitat diversity (pools, riffles, etc.) and placing additional stress on the designated water use.

This protocol was developed to support an interpretation of the New Mexico State Water Quality Standards (NMWQCC, 2000) narrative standard for stream bottom deposits. The current standard for the deposition of material on the bottom of a stream channel is listed in the *State Of New Mexico Standards for Interstate and Intrastate Surface Waters*, Section 1105.A General Standards:

> Bottom Deposits: Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

The following protocol is similar to the approach proposed by the State of Colorado (CDPH&E, 1998) and represents a simple, but quantitative three-step assessment procedure for determining whether the above narrative standard is being attained in a particular stream reach or segment by :1) comparing changes or differences, if any, between the site of concern and a reference site; by 2) directly evaluating instream habitat by measuring two stream bottom substrate parameters or indicators, namely substrate size (mainly fines, 2 mm or less) abundance (pebble count) and cobble embeddedness; and 3) verifying or confirming results obtained in number 2 by assessing and comparing benthic macroinvertebrate communities (or fish) at the same sites. **This protocol is not designed to determine sources, locations, quantities or causes of excess stream bottom sediment**.

# 1. <u>Reference and Study Site</u>

In order to properly assess a study site or stream reach for impairment(s) due to stream bottom deposits, a proper reference site must be selected and classified for comparison. Once this is accomplished, selected "indicators" such as percent fines, embeddedness and biological integrity can be measured and compared between the two sites. Under this protocol, the reference site or condition serves as a quantitative and/or qualitative control or yardstick to which a study (or impacted site) may be compared and evaluated. Reference conditions are used to scale the assessment to the "best attainable" situation. This approach is critical to the assessment because stream characteristics vary dramatically across different regions (Barbour *et al.*, 1996), watersheds or even stream segments. **The ratio between the score for the study site and the reference site (or condition) provides a percent comparability measure for each station**. The station of interest is then classified on the basis of its similarity to expected conditions (reference condition) and its apparent potential to support an acceptable level of biological health (Barbour *et al.*, 1999).

Ideally, the reference and study sites should share similar or common characteristics such as elevation, geology, hydrology, hydraulics, in-stream habitat (pools, substrate, etc) and riparian vegetation. However, if the study site is impaired, such things as channel hydraulics, habitat and streamside vegetation may be different from the reference site simply because the differences observed may either be a cause or a result of a possible departure from the reference condition. Characteristics that cannot change over time should be used as primary attributes of similarity between reference and study sites. Examples of similar attributes are elevation, geology and hydrology (precipitation, etc.). These three characteristics of similarity between a reference and study site can be ensured through the use of ecoregion designations. Simply put, **the study site and the reference site need to be in the same ecoregion**. Currently, the Surface Water Quality Bureau recognizes and/or uses two different ecoregion classifications. The first is a terrestrial system (Omernik, 1987) developed for the United States Environmental Protection Agency (USEPA) while the second is an evolving aquatic classification scheme based primarily on altitude and developed exclusively for New Mexico by its Department of Game and Fish (Cowley *et al*., 1997). To insure that enough similarity exists between a reference and study site so that a valid comparison can be made, both sites should be in the same terrestrial and aquatic ecoregion. For example, sampling site A could be used as a reference for study site B if both sites are located in Omernik ecoregion 21 and NMDG & F ecoregion 1. If, however, only one ecoregion classification scheme can be matched between the reference and study site, it should be the aquatic ecoregion classification. For instance, if sites A and B are in NMDG&F ecoregion 1, but site A is located Omerick ecoregion 21 while site B is in ecoregion 22, the two sites can still be compared.

Additional or secondary characteristics that can be used to supplement and further fine tune the ecoregion similarity between reference and study sites are those that can be readily measured at each site such as watershed size, stream type (Rosgen, 1996) and channel cross-sectional area. In other words, reference and study sites in the same ecoregion having the same stream type (McGarrell, 1998), similar watershed size and cross-sectional area are extremely similar and can be readily compared. Use of these secondary characteristics in evaluating similarities for the pairing of sampling sites needs further study, however, their use as an additional tool for evaluation of sites is encouraged (Barbour et al, 1999). At a minimum, these data can be entered into a database that can later be used in a statistical analysis to determine whether use of these characteristics is valid in site selection protocols.

It should be pointed out that relative quality of every reference site is not equal based on location in a watershed. A tiered approach (CDPH&E, 1998) to establishing the reference condition is based on the quality of reference sites, and is consistent with USEPA technical guidance (Barbour *et al.*, 1996).

Tier 1. Reference sites acceptable and are minimally disturbed or "natural" and described by EPA as the "biological integrity expectation." The following characteristics should be considered in selecting this group of reference sites: a) no upstream impoundments or diversions; b) no point discharges, spills or hazardous waste sites; c) low human, agricultural and road density; and d) minimal nonpoint source problems. An example would be a headwater mountain stream.

Tier 2. Reference sites are acceptable, but are more than minimally disturbed. Where no "natural" site or condition exists, the best available sites are sampled for determination of reference condition or selected based on best professional judgment for the best available site in the ecoregion. USEPA describes these sites as the "interim expectation" because of the potential for restoration to a minimally disturbed or "natural" condition listed in Tier 1.

Tier 3. Reference sites are not acceptable or no reference site exists. Reference conditions would be based on models, historical data, data from neighboring states, ecological information, and/or expert opinion as appropriate.

In summary, the classification of streams based on geographic region (ecoregions) and stream type (Rosgen 1994, 1996) is to reduce the complexity of biological information and improve the resolution or sensitivity of biological surveys by partitioning or accounting for variation between sites. Furthermore, the best classification variables are those that are readily obtained from maps or regional water characteristics such as ecoregion, gradient, alkalinity and hardness. Stream characteristics that are readily affected by human activities or occur as a biological response to physical conditions (i.e., land use, habitat condition or nutrient concentrations) should not be used as classification variables (McGarrell, 1998; Barbour et al, 1999).

## 2. <u>Physical Assessment</u>

In order to assess the stream bottom for contaminants (mainly sediment) that may damage or impair aquatic life and significantly alter the physical properties of the bottom, physical measurements of the stream bottom substrate must be made alongside measurements being made of the biological component. Physical measurements (or indicators) of the stream bottom need to take into account those attributes or characteristics, that potentially promote the best physical habitat or environment for aquatic life independent of water quality. This concept can best be seen in Figure 1 (Plafkin et al., 1989) which shows the relationship between habitat and biological quality. More specifically, substrate that is plentiful, sufficiently large and varied, and is not surrounded or buried by fines appears to offer the best attributes for habitat suitability for many aquatic organisms adapted to such conditions.

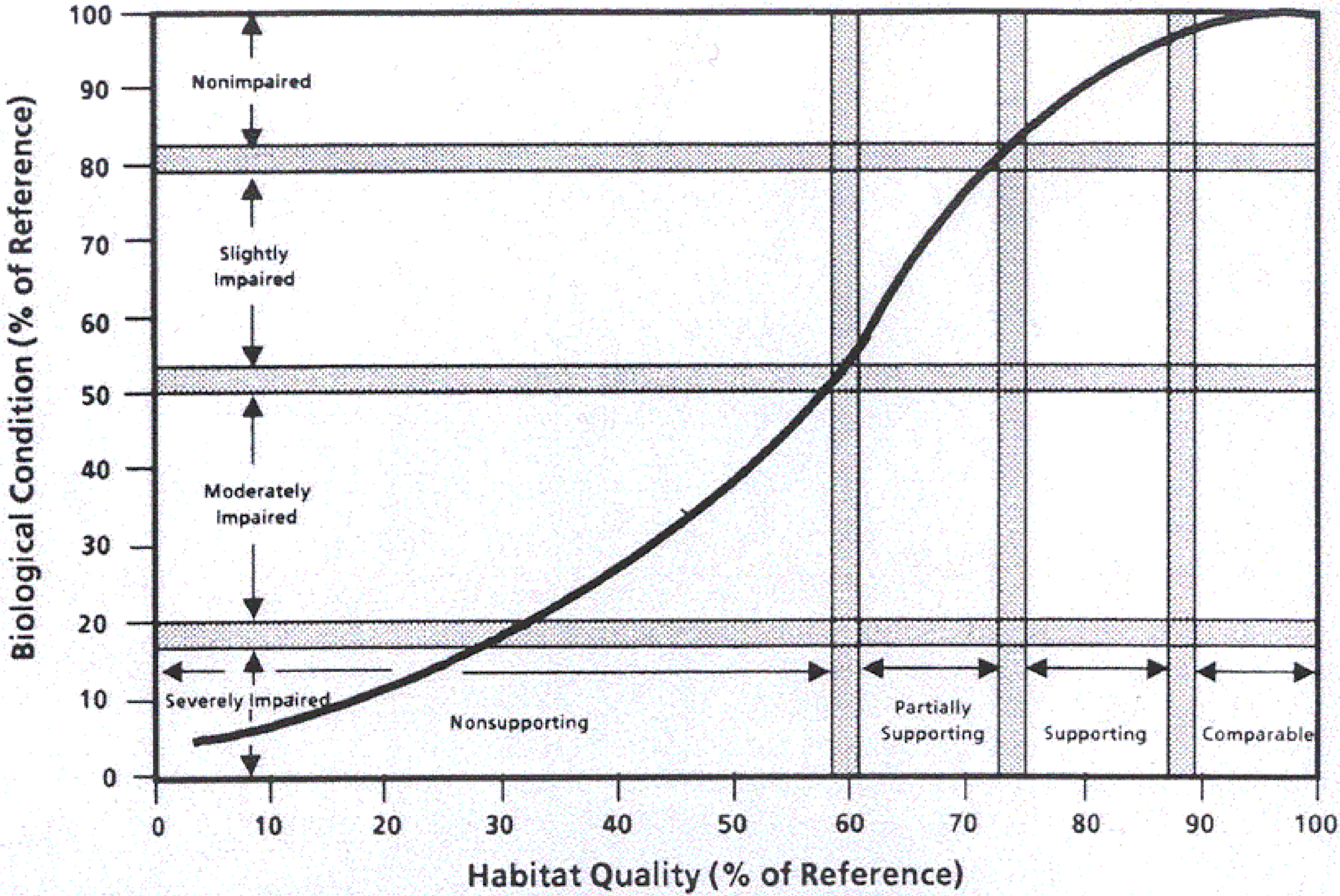


Figure 1. Relationship between habitat and biological condition (Plafkin et al, 1989).

In a study of 562 streams located in four northwestern states, Relyea *et al* (2000) suggested **that changes to invertebrate communities as a result of fine sediment (2mm or less) occur between 20-35% fines**. Chapman and McLeod (1987) suggest that geometric particle size and percent of the bed surface covered by fines should both be used to define habitat quality. These two criteria can be ascertained by performing a **pebble count**. The pebble count procedure provides not only particle size distributions (d50, d84, etc.) and percent class sizes (% sand, % cobble, etc.), but offers a relatively fast and statistically reliable methodology for obtaining this information. In addition, relatively rapid temporal and spatial comparisons can be made at a number of sites within a watershed.

Although sufficient and varied sizes of stream bottom substrate are necessary for biological colonization, protection and reproduction, its full potential may not be realized if the substrate surfaces are surrounded by fine sediment. In streams with a large amount of sediment, the coarser particles become surrounded or partially buried by fine sediment. **Embeddedness** quantitatively measures the extent to which larger particles are surrounded or buried by fine sediment (Mc Donald *et al*., 1991). Studies by Bjorn et al. (1974, 1977) concluded **that approximately one-third embeddedness (33%) or less is probably the normal condition in streams**. Above this condition, however, insect populations decline substantially as habitat spaces become smaller and filled. By performing a **pebble count** and measuring **cobble embeddedness**, the stream bottom can be characterized as an aquatic habitat, compared to a reference site and then tentatively evaluated for impairment due to stream bottom deposits. **Confirmation** of impairment takes place when a stream site is **biologically assessed**.

A. Pebble Count

The pebble count (Wolman, 1954) may be performed separately or as part of a larger stream inventory and assessment study (Rosgen, 1996). The intermediate axis of 100 particles should be measured and tallied using standard Wentworth size classes from 10 equidistant transects (10 particles/transect) selected along a longitudinal stream section consisting of approximately 20 to 30 bankfull widths or two meander wavelengths. Pebble counts may be recorded, tallied and represented using forms provided by Rosgen in the *Reference Reach* field book (Rosgen, 1998). From the raw data, d35, d50, and d85 data should be calculated along with percent composition values for six class types of channel materials ranging from fines (sand, silt and clay) through bedrock.

In order to ascertain and/or evaluate increases in fines and its potential effect on aquatic life at the study (or impacted) site relative to the reference site, the following procedure should be used. If the percent fines at the study site is 30% or less, the site may be evaluated as fully supporting regardless of the percent fines at the reference site. This assumption is derived from the study done by Relyea *et al (*2000) which concluded that changes to the macroinvertebrate community occur between 20-35% fines. If the fines at the study site exceed 30%, divide the percent fines calculated at the study site by those at the reference site and multiply by 100. The **increase** in fines and its effect on aquatic life use may evaluated according to Figure 1 (Habitat Quality) and is as follows: full support (comparable to reference) 0 to 10%; supporting, 11%-27%; partial support, 28%-40%; and non-support, > 40% (Table 1). For example, reference site A was found to have a stream bottom consisting of 30 percent fines while study site B was found to have fines of 40 percent. Dividing 40 percent by 30 percent and multiplying by 100, yields 133 percent or a 33 percent increase (i.e., 40/30 X 100 = 1.33 X 100 =133% - 100 = 33%) in fines. The site would subsequently be evaluated as partially-supporting. It should be noted that the above assessment is only an indicator and needs to be combined with an embeddedness evaluation and confirmed with a biological assessment. Furthermore, data comparing the above increases in fines and its relative impact on biological communities needs to be tested through an adequately designed and maintained data base from which proper causal relationships between fines, embeddedness and biological integrity can be statistically inferred.

B. Embeddedness

Two types of methodologies may be employed for determining cobble embeddedness depending on the nature of the stream bottom substrate as determined by the pebble count. The first was developed by the State of Idaho (Burton and Harvey, 1990) **and should be used only on cobble-bottom or cobble-dominated streams (d50 = 45 mm or greater).** The second method is similar to the first with the exception that calculations performed on the raw data are not weighted to include percent fines in the spaces (intergravel living space) between individual cobbles. This method is used to calculate the simple mean (average) percent-embeddedness of cobble for reference sites on streams that are not cobble-dominated. Cobble embeddedness procedures (obviously) cannot be performed on streams that contain little or no cobble.

1. State of Idaho Embeddedness Procedure

From the pebble count data, determine the d50 value of the stream bottom substrate. If it is found to be 45 mm or greater, proceed with the methodology described in the Idaho embeddedness protocol (Burton and Harvey, 1990). Embeddedness measurements should be performed on the same stream reach where the pebble count was performed. However, in order to avoid processing substrate previously disturbed from the pebble count measurements, cross-sectional transects for the embeddedness measurements should be located in between those used for the pebble count. For example, if the pebble count measurements were performed at cross-sectional transects listed as 0, 20 and 40 feet, etc. along the longitudinal profile of the river, the embeddedness measurements should be done at the distances of 10, 30 and 50 feet, etc. If a laptop computer is not used for field data entry and statistical determination of sample size adequacy, it is recommended that the substrate content of ten hoops (1/transect) be measured.

After performing embeddedness measurements at both the reference site and study site(s), the data should be entered and analyzed using computer program software developed for this procedure by the State of Idaho. The embeddedness derived from this procedure and subsequent analysis is termed a "weighted" embeddedness because it factors in percent fines along with the percent embeddedness of cobble occupying the hoop area being measured (% embeddedness = % hoop area in fines X 100 + remaining % X embedded % / 100). An additional calculation generated by this program is the interstitial-space index (ISI), which is a measure of unembedded substrate. This number should only be used for inclusion in any database that statistically evaluates potential physical "indicators" of sedimentation and their relationship to biological integrity.

As previously mentioned, studies by Bjornn indicate that embeddedness percents of approximately 33% appear to be a "normal" stream condition. Because of this, embeddedness percents of 30 or less encountered at a study site should be assessed as fully supporting regardless of the values measured at the reference site. At values above 30% a comparison of percent embeddedness between the reference and study sites can be performed using a test for significance of means using a 'T' distribution in which the null hypothesis is s=s. If the hypothesis is accepted, then the percent mean embeddedness at both the reference and the study sites is similar and the aquatic life use is therefore supported or not impaired. If, however, the hypothesis is rejected (s≠s) then the study site mean should be divided by the reference mean (as mentioned previously with the pebble count) and multiplied by 100 to determine the percent increase in embeddedness at the study site. The increase in embeddedness and its effect on aquatic life use may be evaluated as follows: full support (comparable to reference), 0 to 10%; supporting, 11%-27%; partial support, 28%-40%; and non-support > 40% (Table 1). This method should be applied to the study site even if the d50 is less than 45 mm and the reference site d50 is 45 mm or greater.

2. Modified Embeddedness Procedure

If the pebble count at a reference site shows the d50 to be less than 45 mm, then the stream is not cobble dominated and the above methodology (1) cannot be used. Instead, the content of 10 hoops from a riffle or cobble-dominated area should be measured for percent embeddedness. However, instead of using the embeddedness software to calculate a "weighted" embeddedness, a simple mean is calculated from each individual cobble measured from the 10 hoops. If the embeddedness value at the study site is of 30% or less, the site should be assessed as fully supporting regardless of the values measured at the reference site. If the embeddedness value at the reference site is greater than 30% then the mean values from the reference and study sites may be analyzed by dividing the study site mean embeddedness by that of the reference site, multiplying by 100, and then using the percent increases (Table 1) to evaluate the study site as to the degree of support. If this modified procedure is used at the reference site, it must be used at the study site to ensure consistency in methodologies.

Table 1. Degree of aquatic life use support due to stream bottom deposits (sediment) as evaluated by increases in either fines or embeddedness, relative to a reference site.[1] Adapted and modified from Figure 1, (i.e. 100 - 90% = 0 - 10%).

| Pebble Count Fines ≤ 2 mm (% increase over reference) | Embeddedness (% increase over reference) | Degree of Aquatic Life Use Support (Presumptive[1]) |
|---|---|---|
| 0 – 10% | 0 – 10% | Full Support, Comparable to Reference [1,2] |
| 11 – 27% | 11 - 27% | Supporting[1] |
| 28 – 40% | 28 – 40% | Partial Support[1] |
| > 40% | > 40% | Non-Support[1] |

[1] Biological assessment necessary for confirmation and statistical database.

[2] Raw percent values of 30%or less for fines and embeddedness at a study site should be evaluated as fully supporting regardless of the percent attained at the reference site.

3. Biological Assessment (Macroinvertebrates)

Since the narrative standard for stream bottom deposits is centered around a biological component, any assessment or evaluation of a stream bottom using physical criteria, such as pebble count and embeddedness, needs to be confirmed using some type of bioassessment. A biological assessment using EPA's Rapid Bioassessment Protocol (Plafkin et al, 1989; Barbour *et al.*, 1999) for macroinvertebrates must be performed at both the reference and study sites in which the pebble count and embeddedness procedures to confirm the evaluations and to provide a database in which to infer or provide a statistical relationship between the physical and biological components. Prior to the collection of macroinvertebrates, a habitat assessment (Plafkin et al., 1989; Barbour *et al.*, 1999) of the site should be performed using both visual observation and measurements made in association with any other studies (pebble counts, embeddedness, Rosgen Level II or III, longitudinal profiles, etc.). This can be compared later with the habitat assessment at the reference site to yield additional information as to other potential sources of use impairment other than sediment. Habitat assessment categories are based on percentages derived from dividing the study site score by the reference site score. Assessment categories and the percent comparability to the reference site (Plafkin et al., 1989) are as follows: comparable to reference, > 90%; supporting, 75-88%; partially supporting, 60-73%; and non-supporting, <58%. The missing 2% value between categories allows adjustments between categories based on professional judgment.

Collections of macroinvertebrates for analysis should be taken in a riffle area and may consist of either three quantitative samples using a Hess sampler or three composited kick samples (semi-quantitative) covering an area of approximately one meter for one minute. For valid comparisons and analysis, sampling procedures must be identical between the reference and study site(s). Procedures for preservation, sorting, enumeration, identification and analysis follow standard Surface Water Quality Bureau and USEPA procedures (Barbour et al, 1999; NMED, 2000).

The application of the biological assessment or degree of impairment is a percentage comparison of the sum of selected metric scores at the study site compared to a selected reference condition (site). Biological groupings will be the same as those defined in the 1998 Surface Water Quality Bureau's document "Procedures for Assessing Standards Attainment" (NMED, 1998) and EPA guidance (Plafkin et al., 1989). In Table 2, those sites achieving a biological assessment score greater than 83 percent of the reference condition will be termed non-impaired. Scores from 54 - 79% will be designated as slightly impaired. Scores of less than 50 percent but greater than 20 percent will be determined as moderately impaired and scores less than 17 percent will be determined to be severely impaired. Percentage values obtained that are in between the above ranges will require subjective judgement as to the correct placement (Plafkin et al., 1989).

Table 2. Biological Integrity Attainment Matrix

| % Comparison to Reference | Biological Condition Category | Attributes[1] |
|---|---|---|
| >83% | Non-impaired | Comparable to best situation to be expected within ecoregion (watershed reference site). Balanced trophic structure. Optimum community structure (composition & dominance) for stream size and habitat quality. |
| 79 – 54% | Slightly Impaired | Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases. |
| 50– 21% | Moderately Impaired | Fewer species due to loss of most intolerant forms. Reduction in EPT index. |
| <17 | Severely Impaired | Few species present. Densities of organisms dominated by one or two taxa. |

[1] Biological attributes from EPA's *Rapid Bioassessment Protocols for Use in Stream and (Rivers,Plafkin et al.1989)*. The Surface Water Quality Bureau has initiated a program of reassessing and refining the biomonitoring protocols and percentages used in this table to better reflect conditions in New Mexico waters.

## Final Assessment: Combined Application of Physical and Biological Assessments

Upon completion of physical and biological assessments for stream bottom deposits (sediments), a final assessment can be determined from the following matrix table (Table 3). This is accomplished by taking the greater increase between percent fines or embeddedness and matching it with the appropriate physical assessment use support category in the far left column. Even though the two percentages will not be identical, it is expected that they will be similar enough to be within the same assessment category of support. The physical assessment use category can then be matched with the biological assessment use category located on the top row to obtain a use support category for aquatic life use based on biological and physical indicators of increased stream bottom sediment. It is noteworthy that under certain situations, the physical indicators may define various levels of full support, while the biological assessment may reveal lower levels of support. In these cases, factors other than sediment alone, such as extremes in pH, low oxygen, temperature, and toxicity, etc. may be responsible for a lowering of biological integrity at a particular site. These other perturbations may then be quantified by examining such things as chemical and physical data collected at or near the site in question.

Table 3. Final assessment matrix for determining aquatic life use support categories by combining physical (% fines & embeddedness) and biological assessments as sediment indicators.

| Biological / Physical | Severely Impaired 0-17% | Moderately Impaired 21-50% | Slightly Impaired 54-79% | Non-impaired 84-100% |
|---|---|---|---|---|
| Non-Support Fines and/or Embeddedness >40% increase[1] | Non-Support | Partial Support | Full Support, Impacts Observed | Full Support, Impacts Observed |
| Partial Support Fines and/or Embeddedness 28-40%increase[1] | Non-Support | Partial Support | Full Support, Impacts Observed | Full Support, Impacts Observed |
| Supporting Fines and/or Embeddedness 11-27% increase[1] | Non-Support[2] | Partial support[2] | Full Support, Impacts Observed | Full Support |
| Full Support Fines and/or Embeddedness <10% increase[1] or raw values of 30% or less at the study site. | Non-Support[2] | Partial Support[2] | Full Support, Impacts Observed[2] | Full Support |

1 In cases where the percent increases of fines and embeddedness for a particular site are not in the same percent category or cell, use the category with the higher percentage between the two. An example, if fines are increased by nine percent and embeddedness is increased by 21 percent relative to the reference site, use the 11-30% or full support, impacts observed category for use in the combination matrix.

2 Reduction in the relative support level for the aquatic life use in this particular matrix cell is probably not due to sediment. It is most likely the result of some other impairment (temperature, D.O., pH, toxicity, etc.), alone or in combination with sediment.

Step by step procedure for evaluating whether sediment is impairing the aquatic life use at a stream site.

1. Select study site(s) along with a comparable reference site.

2. Perform a pebble count and embeddedness evaluation at both the study and reference sites. Remember that the embeddedness methodology employed depends on the d50 value obtained from the pebble count.

3. Perform a bioassessment on the benthic macroinvertebrate communities at each site in which the pebble count and embeddedness evaluations were performed. Biological collections can be done in the same sampling area four weeks after doing the physical evaluations (pebble count and embeddedness) or they may be done just prior to the physical evaluations as long as the collections are done in a similar area downstream of the designated area from which the physical evaluations are to be done. In addition, complete a Rapid Bioassessment habitat form at all sampling sites.

4. Compare the physical and biological data between the study and reference sites by dividing the results obtained at the study site by that of the reference site to obtain percent "comparability."

5. Using the final assessment matrix table (Table 3), locate the proper support cells for both the physical and biological percentages calculated in step 4, and determine the final degree of support for the aquatic life use that is affected by sediment.

Data collection and interpretation

The various support categories, along with the ranges of percents used to quantify the various categories, are based on slight modifications of those used in EPA's Rapid Bioassessment Protocols (Plafkin et al, 1989) and the State of Colorado Sediment Task Force (CDPH&E, 1998). They are intended to provide an initial base or reference point from which to proceed in the collection and interpretation of data regarding the adverse effects of sediment on biological communities in the State of New Mexico. As this guidance is applied and data from various sites are collected, it will be necessary to adjust the standards attainment matrices in terms of the percentage of reference conditions for physical stream bottom substrate "indicators" and biology. It is imperative to the validity, growth and evolution of this document that the Surface Water Quality Bureau establish a proper database from which the valid statistical treatment may be employed to strengthen and adjust the matrix tables when deemed necessary through the addition of data generated from this protocol. In addition, it may be prudent to engage the services of a statistician to review and strengthen this endeavor.

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